Adhesive Contact : a Survey and a Unified Formulation

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ABSTRACT

A brief survey of the most widely used Cohesive Zone Models is first presented and discussed.

Then, a general framework for these laws is given under the form of a unified formulation recently proposed by Del Piero and Raous (Del Piero, Raous [1]).

This unified formulation is based on :
– general laws, typically, energy conservation and dissipation principles, that is, mechanical versions of the first two laws of thermodynamics,
– a set of state variables, that is, an array of independent variables which fully determine the response to all possible deformation processes,
– a set of elastic potential and dissipation potentials, which are functions of state in terms of which the general laws take specific forms,
– a set of constitutive assumptions.

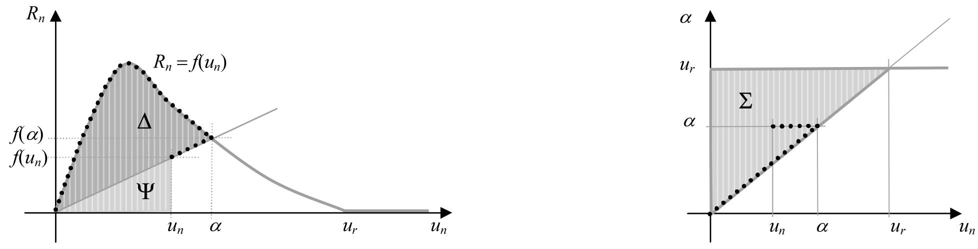
The behavior of the interface is first characterized by two given loading curves $f_n(u_n)$ and $f_t(u_t)$, which are supposed to be star-shaped with respect to the origin, where u_n and u_t are the normal and tangential components of the relative displacement on the interface and R_n and R_t are respectively the components of the contact force. A state variable α is introduced to measure the current intensity of damage. The variables $\{u_n, u_t, \alpha\}$ have to satisfy a set of inequalities which defines the state space. To exemplify this, for the special case where there is no viscosity, the loading curve $R_n = f_n(u_n)$ and the state space are given for the normal components in Fig.1 (a) and (b). The response due to a deformation process of loading-unloading starting from the origin is represented by the dashed line in the force-displacement plane (a) and in the state space (b). As described in [1], the strain energy is then given by :

$$\Psi(u_n, u_t, \alpha) = \frac{1}{2} g_n(\alpha) u_n^2 + \frac{1}{2} g_t(\alpha) u_t^2 \tag{1}$$

where $g_n(u_n) = \frac{f_n(u_n)}{u_n}$ and $g_t(u_t) = \frac{f_t(u_t)}{u_t}$, are the current stiffness of the interface.

The dissipation potential is then deduced from the energy balance evaluated on the force-displacement response (see Fig. 1) :

$$\Phi_d(\alpha, \dot{\alpha}) = -\frac{1}{2}(g'_n(\alpha) + \frac{1}{2} g'_t(\alpha))\alpha^2 \dot{\alpha}. \tag{2}$$



(a) force/displacement (b) State space

FIGURE 1 – Adhesion with damage without viscosity, the normal behavior

When the viscosity is included in the evolution of the damage, a dissipation potential is added :

$$\Phi_v(\alpha, \dot{\alpha}) = \frac{1}{4} h(\alpha)\dot{\alpha}^2 \tag{3}$$

where $h(v)$ is given and defines the viscous dependence ($h(\alpha) > 0$).

In order to introduce the coupling of the adhesion to the friction, the following friction dissipation power is added :

$$D_f(\alpha, R_n^-, \dot{u}_t) = \mu(\alpha) R_n^- \, |\dot{u}_t| \tag{4}$$

where μ is the friction coefficient which is generally a function of α .

Along with the definition of the state of admissible states for (R, u_n, u_t, α), one writes the energy conservation under the form of the power equation :

$$R\dot{u} = \dot{\Psi} + D_d + D_v + D_f \tag{5}$$

and the dissipation principles $\{\ D_d \geq 0; \quad D_v \geq 0; \quad D_f \geq 0\ \}$ which come from the mechanical version of the Clausius Duhem inequality.

Using the power equation (and its first or second derivative when the power equation is identically satisfied) and the previous inequalities, one can obtain the behavior law of the interface including the Signorini conditions and the equations of the evolution equation of α.

The laws presented in the survey could be obtained by choosing appropriated forms of $f_n, f_t, h(\alpha), \mu(\alpha)$. This is illustrated on the RCCM model (Raous et al [2] [3]).

Références

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